FIG. 1

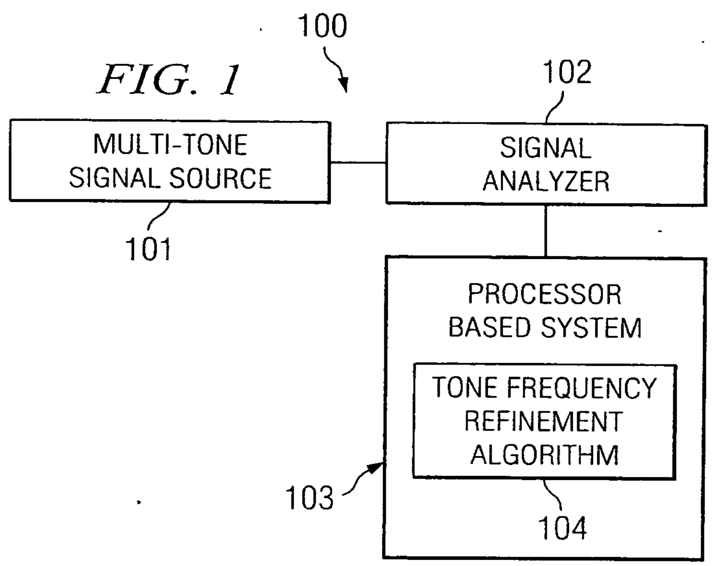
100
102
MULTI-TONE SIGNAL SOURCE
SIGNAL ANALYZER
101
PROCESSOR BASED SYSTEM
TONE FREQUENCY REFINEMENT ALGORITHM
103
104

FIG. 2

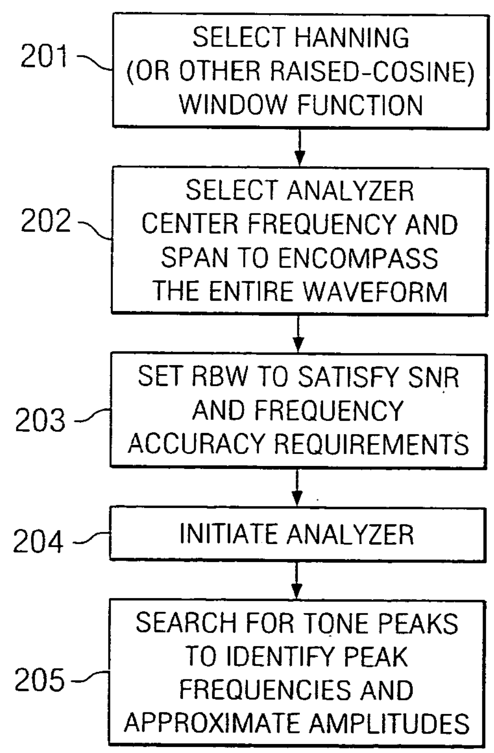
201
SELECT HANNING (OR OTHER RAISED-COSINE) WINDOW FUNCTION
202
SELECT ANALYZER CENTER FREQUENCY AND SPAN TO ENCOMPASS THE ENTIRE WAVEFORM
203
SET RBW TO SATISFY SNR AND FREQUENCY ACCURACY REQUIREMENTS
204
INITIATE ANALYZER
205
SEARCH FOR TONE PEAKS TO IDENTIFY PEAK FREQUENCIES AND APPROXIMATE AMPLITUDES

FIG. 3

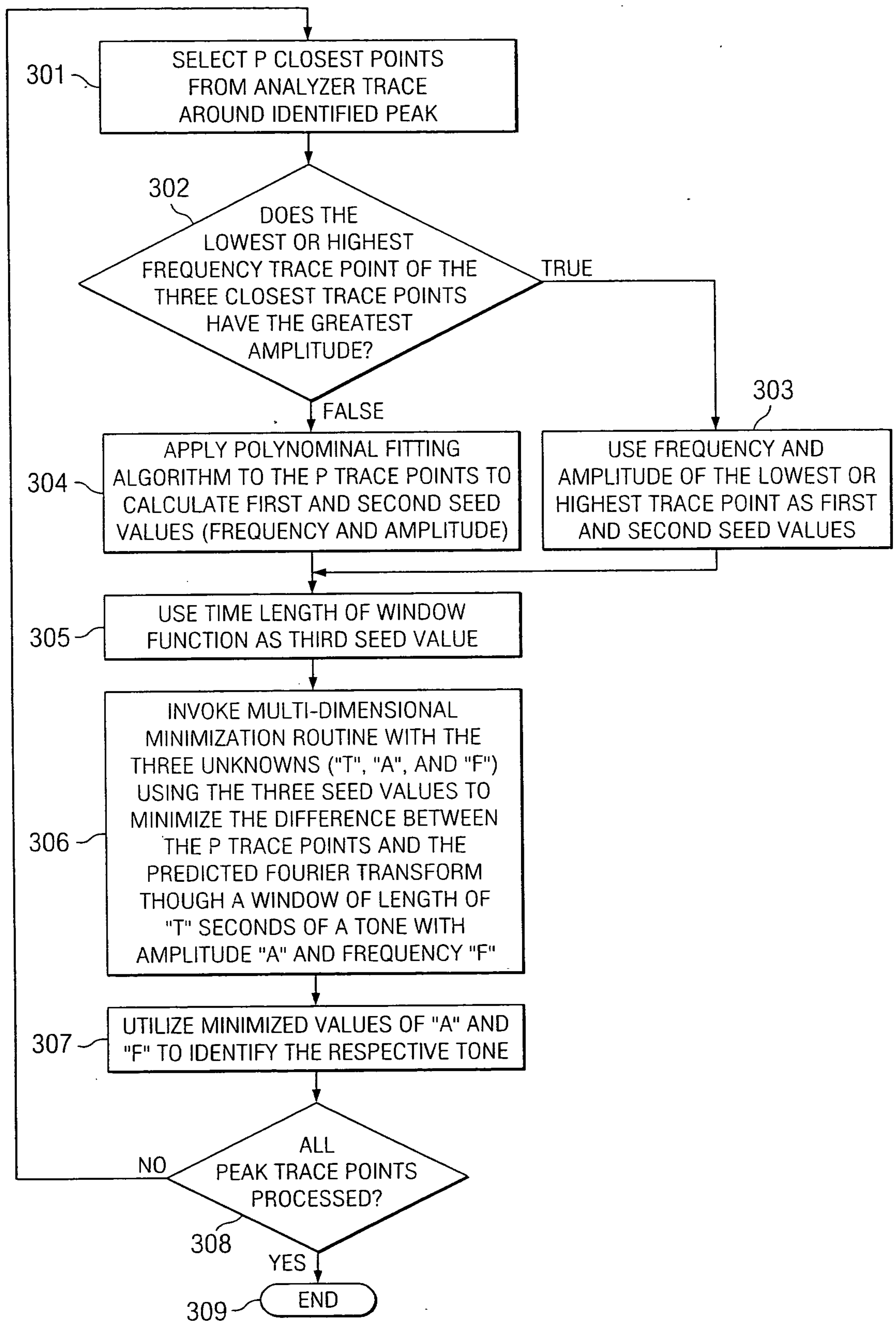
301
SELECT P CLOSEST POINTS FROM ANALYZER TRACE AROUND IDENTIFIED PEAK
302
DOES THE LOWEST OR HIGHEST FREQUENCY TRACE POINT OF THE THREE CLOSEST TRACE POINTS HAVE THE GREATEST AMPLITUDE?
TRUE
FALSE
303
USE FREQUENCY AND AMPLITUDE OF THE LOWEST OR HIGHEST TRACE POINT AS FIRST AND SECOND SEED VALUES
304
APPLY POLYNOMINAL FITTING ALGORITHM TO THE P TRACE POINTS TO CALCULATE FIRST AND SECOND SEED VALUES (FREQUENCY AND AMPLITUDE)
305
USE TIME LENGTH OF WINDOW FUNCTION AS THIRD SEED VALUE
306
INVOKE MULTI-DIMENSIONAL MINIMIZATION ROUTINE WITH THE THREE UNKNOWNS ("T", "A", AND "F") USING THE THREE SEED VALUES TO MINIMIZE THE DIFFERENCE BETWEEN THE P TRACE POINTS AND THE PREDICTED FOURIER TRANSFORM THOUGH A WINDOW OF LENGTH OF "T" SECONDS OF A TONE WITH AMPLITUDE "A" AND FREQUENCY "F"
307
UTILIZE MINIMIZED VALUES OF "A" AND "F" TO IDENTIFY THE RESPECTIVE TONE
308
ALL PEAK TRACE POINTS PROCESSED?
NO
YES
309
END

FIG. 4

400

- FIRST, CHECK THAT THE PEAK OF THE THREE POINTS IS THE MIDDLE POINT. IF NOT, SIMPLY RETURN THE AMPLITUDE AND FREQUENCY OF THE PEAK POINT AND EXIT. 401
- NOW, CALL THE THREE POINTS AMPLITUDES' y1, y2 AND y3. 402
- THE POINT FREQUENCIES' ARE xc-dx, xc, AND xc+dx. 403
- EVALUATE THE "CURVINESS"=(y1-2*y2+y3). 404
- IF "CURVINESS"=0, THEN SIMPLY RETURN THE AMPLITUDE AND FREQUENCY OF THE PEAK POINT AND EXIT, OTHERWISE, CONTINUE. 405

EVALUATE THE FOLLOWING EXPRESSIONS:

- k0=y2; 406
- k1=(y3-y1)*0.5/dx; 407
- k2=CURVINESS*0.5/(dx*dx); 408
- MinMaxX=-k1/(2*k2); 409
- MinMaxY=k0+k1*MinMaxX+k2*MinMaxX*MinMaxX; 410
- MinMaxY1=k0+k1*(MinMaxX+dx)+k2*(MinMaxX+dx)*(MinMaxX+dx); 411
- Maximum=(MinMaxY>MinMaxY1 ? 1 : 0); 412
- MinMaxX=MinMaxX+xc; 413
- IF MAXIMUM IS NOT 1, THEN A MAXIMUM WAS NOT FOUND, SIMPLY RETURN THE AMPLITUDE AND FREQUENCY OF THE PEAK POINT, 414
- OTHERWISE, THE NEW VALUES MinMaxX AND MinMaxY ARE RETURNED TO THE SEED VALUES FOR SIGNAL FREQUENCY (Hz) AND AMPLITUDE (dBm). 415

FIG. 5

$$\frac{\partial Err}{\partial A} = \sum_{p=1}^{P} S_p \frac{\sin x}{ax}\left[\frac{a-b}{\left(1-\frac{\pi^2}{x^2}\right)} + \frac{a}{\left(1-\frac{x^2}{\pi^2}\right)}\right] \quad 501$$

$$\frac{\partial Err}{\partial T} = \sum_{p=1}^{P} \frac{S_p A}{T}\left[\frac{a-b}{a\left(1-\frac{\pi^2}{x^2}\right)}\left(\cos x - \frac{\sin x}{x} - \frac{2\pi^2 \sin x}{x^3\left(1-\frac{\pi^2}{x^2}\right)}\right) + \frac{1}{\left(1-\frac{x^2}{\pi^2}\right)}\left(\cos x - \frac{\sin x}{x} - \frac{2x\sin x}{\pi^2\left(1-\frac{x^2}{\pi^2}\right)}\right)\right] \quad 502$$

$$\frac{\partial Err}{\partial \omega} = \sum_{p=1}^{P} \frac{S_p A}{\omega_p}\left[\frac{a-b}{a\left(1-\frac{\pi^2}{x^2}\right)}\left(\cos x - \frac{\sin x}{x} - \frac{2\pi^2 \sin x}{x^3\left(1-\frac{\pi^2}{x^2}\right)}\right) + \frac{1}{\left(1-\frac{x^2}{\pi^2}\right)}\left(\cos x - \frac{\sin x}{x} + \frac{2x\sin x}{\pi^2\left(1-\frac{x^2}{\pi^2}\right)}\right)\right] \quad 503$$

$$\left[\frac{a-b}{a\left(1-\frac{\pi^2}{x^2}\right)}\left(\cos x - \frac{\sin x}{x} - \frac{2\pi^2 \sin x}{x^3\left(1-\frac{\pi^2}{x^2}\right)}\right) + \frac{1}{\left(1-\frac{x^2}{\pi^2}\right)}\left(\cos x - \frac{\sin x}{x} + \frac{2x\sin x}{\pi^2\left(1-\frac{x^2}{\pi^2}\right)}\right)\right] \longrightarrow \frac{-1}{4}\left[\frac{(a-b)}{a}+3\right] \quad 504$$